

# FINAL REPORT

for

Multi-Dimensional Data Assimilation for Physical-Biological Models

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Submitted by

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**Long-term Goal:** The long-term goal of our research is to develop mathematical models that can be used to obtain better understanding of the interactions between physical and biological processes in marine ecosystems and their role in structuring marine food webs.

**Objectives:** To accomplish our long-term goal we pursued the following research objectives: 1) develop approaches for assimilating multidisciplinary measurements into marine ecosystem models; 2) test the approaches in a range of ecosystem models; and 3) develop approaches for determining the frequency at which data need to be assimilated into ecosystem models. These research objectives are directed at developing techniques and approaches that are needed for the full capability of multidisciplinary measurement programs to be realized.

**Approach:** The amount and type of data needed for input to data-assimilative multi-component marine ecosystem models are currently determined empirically for each model. This approach lacks rigor and generality and results in data-assimilative approaches that are specific for a particular situation or simulation. Empirical

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Orthogonal Function (EOF) techniques were used in an attempt to determine data needs for marine ecosystem models. Using EOF analysis, data can be decomposed into orthogonal functions and their corresponding temporal coefficients. These EOF structures allow determination of the primary interconnections of the ecosystem, which in turn, allows insight into the processes that need to be well represented in the corresponding forward model. The EOF model uses the eigenstructures from a given data set and modifies a forward model with the aim of nudging the model towards the prescribed data set. The overall approach may be useful for combining data and forward models in a data assimilative mode.

**Results:** A five component, three-depth marine ecosystem model was developed to mimic the spring bloom in the upper Chesapeake Bay. In numerical twin experiments, the EOF model was able to accurately reproduce this forward model using only a limited number of eigenstructures. However, when the Chesapeake Bay data was used to create the eigenstructures, the EOF model was able to approximate the forward model only when the full complement of eigenstructures was used. Analyses show that the EOF model is sensitive to perturbations of the eigenstructures, which suggests that the dynamics of the forward model are not appropriate for the data set, different formulations are needed in the model, or that a reworking of the eigenstructures is needed. Additional modeling studies using data sets from a microcosm, which is a more controlled environment, show that the EOF model improved data reproducibility even when a reduced number of eigenstructures was used. These results imply that: 1) the dynamics of the forward model developed for the Chesapeake Bay ecosystem are not appropriate for the data set that was used as input, 2) different formulations are needed for the biological and physical processes included in the ecosystem model, 3) that the eigenstructures need to be modified such that the eigenstructures correctly correspond with the model processes represented by the eigenstructures, or 4) a combination of the previous is needed. The approach used in this modeling study potentially provides a powerful method for evaluating data-model consistency and for determining data needs for marine ecosystem which are important factors in combining data and forward models in a data assimilative mode.

**Work Completed:** The Chesapeake Bay and microcosm ecosystem models, which are representative of each of the data sets used in the study, have been developed, as has the corresponding EOF model. Simulations with these models and corresponding analyses have been completed. Presentations on the models and EOF results were given at the 1998 Fall Meeting of the American Geophysical Union and the 2000 Ocean Sciences Meeting. A manuscript describing the integration of EOF techniques into marine ecosystem models has been submitted to *Journal of Marine Research*. A second manuscript which considers the use of the EOF model with a data assimilative marine ecosystem model is in preparation.

**Impact/application:** Our results show that the combined EOF-data assimilation model is a promising approach for combining data and models at certain space and time scales. The approach also provides a diagnostic procedure for determining the level of mismatch between dynamics included in the forward model and those included in the data sets input to the model.

**Related Projects:** The results of this research are being used to develop data assimilative biological models in a project that is funded through the U.S. Joint Global Ocean Flux Study, Synthesis and Modeling Program, which is funded by the National Science Foundation and the National Aeronautics and Space Administration.

**Personnel:** This project provided support for Mr. A.G.E. Haskell, who was responsible for the development of the ecosystem-EOF model.

**Publications:**

Haskell, A.G.E., J.M. Klinck, and E.E. Hofmann, EOF Technique Applied to a Multi-Component Ecosystem Model, *EOS*, 79(45), F432, 1998.

Haskell, A.G.E., E.E. Hofmann, and J.M. Klinck, EOF Techniques Integrated in Marine Ecosystem Models, *EOS*, 80(49), OS65, 1999.

Haskell, A.G.E., E.E. Hofmann, and J.M. Klinck, EOF Techniques Integrated in Marine Ecosystem Models, *Journal of Marine Research*, submitted.

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14. ABSTRACT  This study focused on the development of Empirical Orthogonal Function (EOF) techniques that can be used to determine data needs for marine ecosystem models. The EOF structures allow determination of the primary interconnections of the ecosystem, which in turn, allow insight into the processes that need to be well represented in the forward model developed for a particular ecosystem. The method was tested with a model developed to simulate time development of lower trophic levels observed in an enclosed microcosm. For this system, the EOF model improved data reproducibility even when a reduced number of eigenstructures was used. The results imply that the model and data were inconsistent. The EOF approach used in this study potentially provides a powerful method for evaluating data-model consistency, and for determining data needs for marine ecosystem models, which are important factors in combining data and forward models in a data assimilative mode.						
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